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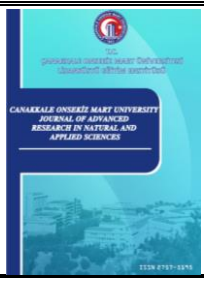

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Merchant Fleet Performance of Türkiye: A CRITIC-based TOPSIS Approach

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Abstract − The study focuses on assessing the merchant fleet performance of Türkiye, a country surrounded by seas on three sides and holding a pivotal position in global logistics networks. It considers mean age of vessels, total carrying capacity in dead weight tons, and the number of ships as indicators influencing Türkiye's merchant fleet performance, with the importance weights of these indicators determined using the CRITIC method. Based on the determined weights, Türkiye's merchant fleet performance for the years 2011-2023 is evaluated using the TOPSIS method. The findings reveal that mean age of vessels emerges as the indicator with the highest importance weight. The analysis indicates an improvement in Türkiye's fleet performance between 2011 and 2013, followed by a subsequent decline from 2013 onwards. Notably, there is a significant shift observed in 2016 across all three indicators. Given Türkiye's aging fleet, the study suggests a focus on acquiring young and high-capacity vessels to enhance fleet performance. This strategic approach can help Türkiye optimize its maritime trade capability and maintain competitiveness in the global shipping industry.

Keywords − *Merchant fleet performance, Türkiye, CRITIC, TOPSIS*

1. Introduction

Türkiye is situated at the intersection of Europe and Asia and its advantageous location along important trade routes has shaped its current prominence in international business. Türkiye's merchant fleet is an essential component of the global maritime network, with a varied fleet composition that meets a range of cargo demands and trade routes [1]. Erdogan and Cetin [2] highlights the crucial role of maritime transport in Turkish economy, particularly in facilitating trade with Asia, Africa, and Europe. This is further emphasized by Cerit [3], who identifies maritime transport as a key factor in the competitive advantage of Turkish exporters. The sector's contribution to Türkiye's industrial development, employment, and trade balance emphasizes economic significance. Nevertheless, despite these advantages, problems like complicated regulations, inadequate infrastructure, and environmental issues still exist, calling for a sophisticated approach to fleet management. The maritime transportation sector in Türkiye has gained substantial significance since the 1980s, with its importance only being recognized in more recent times [4].

Identifying the distinctive features of Türkiye's merchant fleet performance in the geopolitical, economic, and environmental context can enable the formulation of specific policy recommendations tailored to its needs. From a geopolitical perspective, Türkiye's unique geopolitical position as a bridge between Europe and Asia and its access to key waterways such as the Bosphorus make the performance of its merchant fleet critical for global trade [5]. Understanding how Türkiye's fleet competes in this strategic location can contribute to a

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broader understanding of international maritime dynamics. From an economic perspective, analyzing the performance of Türkiye's merchant fleet, a large emerging market with a diverse economy, can provide insights into the economic factors affecting the efficiency and competitiveness of the maritime sector [6]. From an environmental perspective, analyzing the performance of Türkiye's merchant fleet, which like many other countries is subject to various environmental regulations and international standards in the maritime sector, can provide insight into the extent to which the country complies with these regulations and address environmental sustainability concerns [7]. In this study, we aim to analyze the performance of the merchant fleet of Türkiye in more depth. In this context, we seek answers to the questions, specifically (i) what are the strengths and weaknesses of Türkiye's merchant fleet performance using multi-criteria decision-making methods and how do they compare to global benchmarks? (ii) how has Türkiye's merchant fleet performance changed over the years?

This paper is structured as follows: Section two presents the literature review. Section three describes the dataset and methods used. Section four presents the findings and offers a detailed overview. Finally, the study concludes with a discussion of the findings in relation to the existing literature, as well as an exploration of limitations, implications, and directions for future research.

2. Literature Review

Studies on maritime competition and the search for policies to promote national shipping emphasize this situation and offer various policy recommendations. For instance, Gardner et al. [8], Leggate and McConville [9] and Brownrigg et al. [10] on the UK, Morris [11] on Australia, Coto-Millan [12] on Spain, Yercan [13] on Türkiye, Damachi and Zhaoshen [14] on Nigeria, [15] and Iheduru [16] on West and Central Africa, Sawiczewska [17] on Poland, Song [18], and Chiu [19] on China. In terms of cross-country comparisons, Marlow and Mitroussi [20] comparatively examined the tonnage tax regimes of the United Kingdom, Netherlands, Liberia, Panama and Greece and found that Panama is the most favorable regime and the United Kingdom is the least favorable regime under the scenario considered and that some of Greece's international rankings deteriorate as the age of the ship increases.

The performance of Türkiye's merchant fleet is subject to a range of influencing factors, as indicated by various studies. Cetin et al. [6] underscores the significance of competitiveness within the coaster market, while Yilmaz [21] evaluates the Port State Control (PSC) performance of Turkish-flagged ships, reporting favorable PSC performance. Karahan and Kirval [22] quantitatively assessed and visually map the primary attributes of the Turkish maritime transportation sector by employing a cluster approach and emphasized the potential of Istanbul county, also Karahan and Kirval [23] asserted that the maritime sector in Istanbul possesses substantial potential to evolve into a prominent maritime cluster, not only within its regional context but also on a global scale. While the observed statistical significance of clustering on firm performance is notable, the magnitude of this impact was found to be moderate rather than high. According to Ciftci [24], maritime merchant fleet are generally at or below the expected minimum levels relative to income levels in high-income countries with institutionalized market economies. Even in countries with effective maritime policies, the industry is adversely affected by high international competition. Furthermore, due to the extremely low GDP per capita levels in countries such as Russia, India, Indonesia and China, including Türkiye, it is only possible to maintain the existing capacities in merchant fleet formation, which requires high investment expenditures. Cetin et al. [6] emphasized that one of the most important factors hindering the competitiveness of the Turkish owned merchant fleet is the operation of old and outdated small sized general cargo vessels. As mentioned by Kaya and Erginer [25], the mean age of vessels owned by Turkish shipowners exceeds the global fleet average by

5.2 years. Another implications of Cetin et al. [6] is that In instances where funding is required, equity is predominantly utilized, although it frequently proves inadequate. Access to financial resources for modernization or the establishment of new fleets remains insufficient, prompting the pursuit of public support. Moreover, employment of inexperienced and mostly unqualified seafarers on small sized vessels leads to significant risks, and that a business model far from institutionalization is adopted, with family-owned companies dominating the sector.

Baser [4] examined the evolution of the Turkish merchant fleet since 1980, specifically focusing on the selection of technology and the overall productivity of the fleet. Accordingly, a critical issue within the Turkish merchant fleet is the aging of shipbuilding technology, representing a significant challenge in the industry. In addition, it was identified that the productivity of merchant fleet of Türkiye lags behind that of the global merchant fleet. Yercan [13] provided an overview of policy decisions made by Turkish authorities on both international and national fronts. Erdogan and Kara [26] employed a SWOT-AHP integrated method to determine the optimal approach for Türkiye's maritime transportation policy, highlighting the utilization of strengths to exploit opportunities as the most effective strategy in the former study. Kadioglu [27] traced the progression of Türkiye's maritime sector from an inward-oriented strategy to a partially liberal policy, followed by a planned development period, while also assessing the attainment of stated targets. Together, these studies provide a comprehensive insight into Türkiye's maritime transportation policy.

Celik et al. [28] developed a practical decision support mechanism aimed at facilitating a comprehensive multiple criteria analysis for the selection of ship registries using fuzzy AHP methodology and utilized with a case investigation on Turkish maritime industry. Results suggest that ship registries of Türkiye, Panama, and Malta have been selected for evaluation as potential alternatives for Turkish ship owners. Çelik and Topçu [29] conducted a quantitative decision analysis to address the flagging out issue within the Turkish shipping fleet. They evaluated shipowners' decision-making preferences among the Turkish National Shipping Registry (TNSR), Turkish International Shipping Registry (TISR), and Open Registries (ORs) as potential alternatives. The findings of this case study highlight a notable inclination among Turkish shipowners to register with ORs. Consequently, the study suggests that implementing significant changes in TNSR procedures could enhance competitiveness in the international shipping market. One of the model proposals concerning the flagging out issue in the Turkish maritime sector is a fuzzy quantified Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis developed by Çelik and Kandakoğlu [30]. An original model, the 'flagging out strategy development and evaluation matrix' (FODEM), holds promise in offering a structured decision-making tool for addressing the flagging out dilemma consistently.

Existing literature on maritime transport of Türkiye predominantly focuses on flagging out [29,30], market structure [6, 22, 23], and maritime policies [13, 26, 27]. Within the scope of merchant fleet performance, as far as we found out the studies are limited with fleet productivity [4] and PSC performance [21], and there is no comprehensive study on the factors affecting merchant fleet performance. Consequently, this study is anticipated to make a substantial contribution by addressing this gap and providing insights into the performance of merchant fleet of Türkiye.

3. Data and Methodology

The UNCTADstat database offers a variety of sub-indicators under the category of “Maritime Transport” [31]. However, when examining Türkiye’s data based on beneficial ownership, only two indicators are available: "deadweight tons in thousands" and "number of ships." In contrast, a broader range of indicators is accessible based on the flag of registration. In this study, Türkiye’s data has been meticulously reviewed to provide a

comprehensive analysis. The study spans the years 2011 to 2023 and encompasses key indicators such as "deadweight tons," "number of ships," and "mean age of vessels." By focusing on these indicators, the study aims to offer a thorough examination of Türkiye's merchant fleet performance over the specified timeframe, shedding light on trends, patterns, and potential areas for improvement within the country's maritime industry. The CRITIC method has been employed to assign weights to the indicators used in the study. With these weights determined, the TOPSIS method was then applied to measure performance and rank Türkiye's merchant fleet performance by year. This approach allows for a comprehensive evaluation of Türkiye's maritime industry over the analyzed period, offering insights into its relative performance and potential areas for enhancement.

3.1. CRITIC Weighting Method

CRITIC (Criteria Importance Through Intercriteria Correlation) method is used to determine the importance levels of the criteria in the data based on correlation [32].

The CRITIC method offers a superior approach for determining the importance levels of criteria in data based on correlation due to its ability to account for interdependence between criteria, robustness to data variability, reduction of subjectivity through objective measures, handling of multicollinearity, provision of decision support, and adaptability to diverse contexts. By considering the complex relationships between criteria, CRITIC provides more accurate and reliable importance rankings, making it a valuable tool for decision-making in various fields. The steps of probability weights with the CRITIC method are shown in Table 1 as follows.

Table 1. Algorithm of CRITIC weighting method

1.Step: Decision Matrix	$A = [a_{ij}]_{mxn}$
2.Step: Normalized benefit-cost matrix	$\bar{a}_{ij} = \frac{a_{ij} - {a_j}^{ideal^-}}{{a_j}^{ideal^+} - {a_j}^{ideal^-}}$, where ${a_j}^{ideal^-}$ and ${a_j}^{ideal^+}$ represents negative and possitive ideal solutions, respectively.
3.Step: Symmetric matrix	$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}}$, where $a_{ij} \in A$
4.Step: Information load	$c_j = \sigma_j \sum_{i=1}^{m} (1 - r_{ij})$, where standart deviation and measure of conflict calculated by $\sigma_j = \sqrt{\frac{1}{k-1} \sum_{i=1}^{m} (r_{ij} - r_j)^2}$ and $\sum_{i=1}^{m} (1 - r_{ij})$ equations, respectively.
5.Step: Probability weight	$w_j = \frac{c_j}{\sum_{i=1}^{m} c_j}$, where c_j correspon to each elemnt of information load.

3.2. TOPSIS Sorting Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was used to investigate the change and ranking of the number of ships, mean age of vessels and DWT variables by years [33]. It was proposed by Hwang and Yoon [33] to determine the best alternative based on a consensus solution. The method of determining the solutions that are closest to the ideal solution and farthest from the negative ideal solution is called consensus (optimum) solution [34].

The TOPSIS technique was selected due to its alignment with the data and research goals, assessing the performance of Turkey's merchant fleet using specific metrics such as the average age of vessels, cargo capacity, and number of ships. Its ability to facilitate precise, quantitative decision-making renders it well-suited for ranking options based on their proximity to the optimal solution. In comparison to other methods, such as Intuitionistic Fuzzy TOPSIS, conventional TOPSIS is more straightforward and computationally efficient, making it the preferred choice for evaluating Turkey's fleet performance from 2011 to 2023 with defined metrics and minimal uncertainty. TOPSIS ranking steps are shown in Table 2 as follows.

Table 2. Algorithm of TOPSIS sorting method

1. Step: Decision Matrix	$A = [a_{ij}]_{mxn}$, where a_{ij}correspond to each element of criteria
2. Step: Normalized Matrix	$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$, where r_{ij} denotes the elements of the normalized matrix $N = [r_{ij}]_{mxn}$.
3.Step: Weighted Normalized Matrix	It consists of the elements $v_{ij} = w_j r_{ij}$ and is denoted as $V = [v_{ij}]_{mxn}$, where $\sum_{j=1}^{n} w_j = 1$ and $r_{ij} \in N$.
4. Step: Ideal and Non-Ideal Solutions	Ideal and negative ideal separation measures are calculated with weighted matrix elements as $S_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}$ and $S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}$, respectively.
5. Step: Similarity to Ideal Solution measure	The optimum solution is determined by the $C_i^+ = S_i^- / (S_i^- + S_i^+)$ ratio, where $0 \leq C_i^+ \leq 1$.

4. Findings

In this section, first the importance weights of performance indicators were determined for each year between 2011 and 2023 by employing the CRITIC method, which assigns weights to the indicators based on their relative importance. Subsequently, the TOPSIS approach is utilized to measure the merchant fleet performance and compare the years. The weights derived from the CRITIC method are applied to the TOPSIS method to evaluate and rank the performance of each year, allowing for a comprehensive analysis of Türkiye's merchant fleet performance over the specified timeframe. Table 3 presents the mean age of vessels, total carrying capacity in dead weight tons, and the number of ships, which serve as indicators of the merchant fleet performance of Turkish flagged ships from 2011 to 2023.

Since each of the indicators used to measure merchant fleet performance has a different unit of measurement, it would not be useful to show the trend of each indicator over the years on a single figure. Therefore, all three indicators are normalized with the 0-1 normalization method and the movement of the indicators between 2011 and 2023 is shown in Figure 1. This visual representation offers insights into the trends and patterns observed in Türkiye's merchant fleet over the specified period.

Table 3. Raw Data and Normalized Data

Years	Indicators			Normalized Indicators		
	Mean Age of Vessels	**Dead weight tons (in thousands)**	**Number of Ships**	**Mean Age of Vessels**	**Dead weight tons (in thousands)**	**Number of Ships**
2011	25	8753	1315	0,50	0,66	0,89
2012	24	9680	1333	1,00	0,89	1,00
2013	24	10132	1325	1,00	1,00	0,95
2014	25	8738	1254	0,50	0,65	0,53
2015	25	8557	1241	0,50	0,61	0,46
2016	26	8629	1267	0,00	0,62	0,61
2017	26	8241	1266	0,00	0,53	0,60
2018	26	7975	1256	0,00	0,46	0,54
2019	26	7559	1242	0,00	0,36	0,46
2020	26	7064	1241	0,00	0,23	0,46
2021	26	6301	1184	0,00	0,04	0,12
2022	26	6129	1164	0,00	0,00	0,00
2023	26	6651	1170	0,00	0,13	0,04
Mean	25,46	8031,46	1250,62	0,27	0,48	0,51
Median	0,78	1241,93	54,55	0,39	0,31	0,32
S.Dev	26,00	8241,00	1254,00	0,00	0,53	0,53
Min	24,00	6129,00	1164,00	0,00	0,00	0,00
Max	26,00	10132,00	1333,00	1,00	1,00	1,00
Coef. Var	0,03	0,15	0,04	1,44	0,65	0,63

In the normalization step, two distinct perspectives were taken into account: cost and benefit. Each criterion was approached differently to ensure a comprehensive evaluation. For the cost-oriented age criterion, the formula (xmax-x)/(xmax-xmin) was applied. This formula efficiently scales the data, allowing for a clear comparison of the costs associated with different age values. On the other hand, for the benefit-oriented criteria such as dwt (deadweight tonnage) and the number of ships, a different normalization formula was utilized. Here, (x-xmin)/(xmax-xmin) was employed. By using this formula, the focus shifts to the benefits derived from these criteria, enabling a fair assessment of their contributions relative to the entire range of data. These distinct approaches ensure that both the costs and benefits associated with each criterion are effectively considered during the normalization process, leading to a more balanced and insightful evaluation of the decision-making factors.

According to the findings, the mean age of vessels has remained constant since 2016. This indicates that there have been some attempts to keep the mean age of vessels constant or reduce it since this year. According to UNCTAD Review of Maritime Transport [35], 87.9% of bulk carriers, 78.7% of container ships, 65.1% of oil tankers and 42.8% of general cargo ships in the world merchant fleet are 19 years old or younger. When analyzed on the basis of total carrying capacity and number of vessels, it is observed that the indicator values reached a peak in 2013 but have been on a downward trend since then. Especially in 2016, it can be stated that a breakthrough was experienced in terms of all three indicators. Finally, there is also a downward trend in the number of vessels. The fact that the mean age of vessels has remained constant over the years suggests two scenarios. The first one is the inclusion of younger vessels in the fleet and the second one is the disposal of older vessels by directing them to the second-hand or demolition markets. However, the downward trends in total carrying capacity and the number of vessels imply that the latter scenario is more probable.

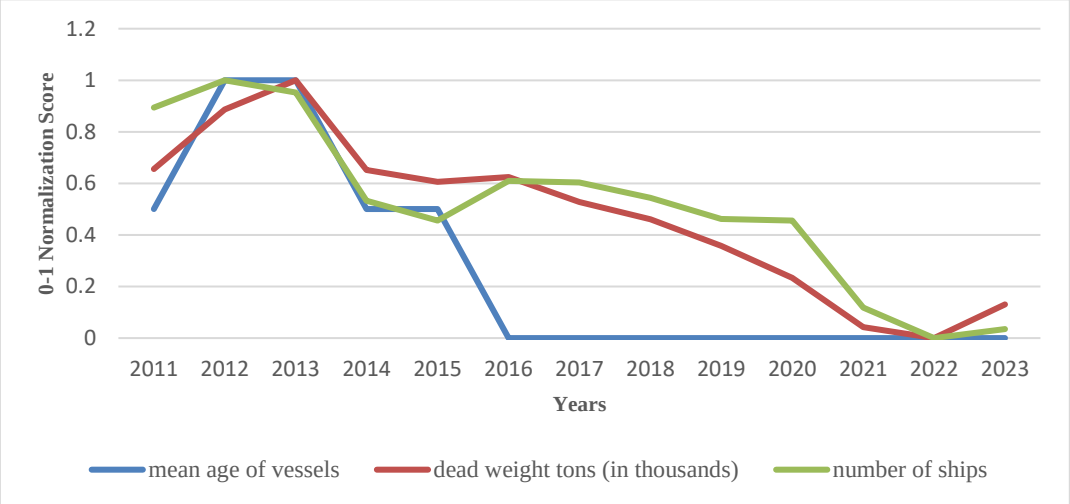

Figure 1. Visualization of the indicators based on 0-1 normalization scores by years

CRITIC method, one of the objective weighting methods, was used to determine the extent to which indicators are effective in Türkiye's merchant fleet performance, and the findings are given in Table 4.

Table 4. Weights and rankings of indicators

	Mean Age of Vessels	Dead weight tons	Number of Ships
σ	0.388125	0.310251017	0.322784
Cj	0.17524	0.07955129	0.1103753
Wj	47.99%	21.78%	30.23%
Rank	1	3	2

The most determinant indicator in Türkiye's merchant fleet performance is the mean age of vessels with a weight of 47.99%. This indicator is followed by the number of ships with a weight of 30.23% and total dwt with a weight of 21.78%. Türkiye's merchant fleet performance score between 2011 and 2023 is calculated by TOPSIS method using the weights obtained from the CRITIC method and the yearly change in the performance score is visualized with a line graph as shown in Figure 2.

Years	Score	Rank
2013	0.753464	1
2012	0.726215	2
2011	0.664766	3
2016	0.65016	4
2014	0.620122	5
2017	0.576564	6
2015	0.575698	7
2018	0.52126	8
2019	0.440594	9
2020	0.366133	10
2023	0.281591	11
2021	0.258525	12
2022	0.245006	13

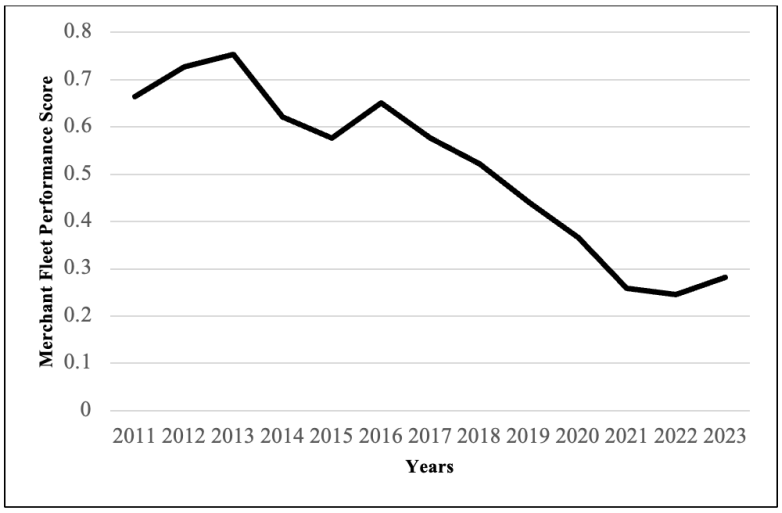

Figure 2. Merchant fleet performance score and rankings

Accordingly, Türkiye's merchant fleet performance score between 2011 and 2023 is on a downward trend and the most important reason for this is the aging of the fleet based on the findings of the CRITIC method. In addition to the aging of the fleet, the decline in the number of ships and total carrying capacity has made the decline in fleet performance inevitable. In line with the changes in the indicators, Türkiye's fleet performance showed a negative break in 2016.

Finally, the box plot in Figure 3 shows some descriptive statistics on Türkiye's merchant fleet performance score between 2011 and 2023.

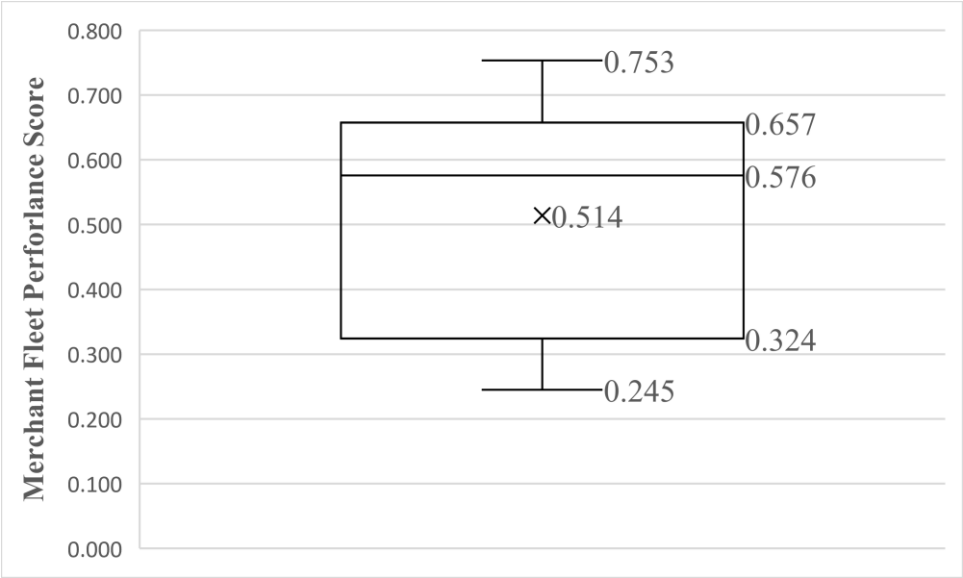

Figure 3. Merchant fleet performance score box plot

Accordingly, Türkiye's average merchant fleet performance for the years analyzed is 0.514. The lowest score among these years was 0.245, while the highest score was 0.753. When the third quartile value is taken into account, it is observed that the performance score is below 0.657 in 75% of the analyzed time period, and

according to the first quartile value, it is below 0.324 in 25% of the analyzed time period. The median merchant fleet performance score for Türkiye in the years analyzed was 0.576. In other words, fleet performance was below 0.576 in half of the time period and above 0.576 in the other half.

5. Discussion and Conclusion

In today's global economy, where services outweigh goods, maritime transportation stands out as the key for international movement and in this study, it is intended to evaluate the performance of merchant fleet of Türkiye that plays a crucial role in global logistics networks. Türkiye needs to boost its merchant fleet's competitiveness, but high costs pose challenges. Findings implies that incentive mechanisms are vital to spur development in maritime capabilities. Accordingly, to boost the Turkish merchant fleet, focus should shift to fleet rejuvenation as also depicted by Cetin et al. [6]. Since 2013, the fleet has aged, remaining at 26 since 2016. In line with Baser [4], prioritizing the replacement of older vessels with newer ones will enhance fleet efficiency. This means disposing older ships through the second-hand market or scrapping and acquiring younger ones. The study suggests efforts to rejuvenate the fleet, but they are insufficient. As asserted by Kaya and Erginer [25], the average age of Turkish fleet exceeds that of the world merchant fleet. Older vessels in Türkiye's fleet are being sold or scrapped to prevent the fleet's average age from rising. However, there is a lack of action to introduce new or younger ships, which would lower or at least maintain the average age. As the total carrying capacity declines due to limited acquisition of younger vessels, industry players should prioritize investing in vessels with significant carrying capacity. This strategic shift will improve all key fleet performance indicators: age, carrying capacity, and number of vessels, leading to overall enhancement in Türkiye's merchant fleet performance. At this point, it would be appropriate to emphasize the average vessel size. The implications of average vessel size can be evaluated from two different perspectives. A larger average ship size may suggest a fleet composed of fewer but more capacious vessels, potentially indicating economies of scale and operational efficiency as supported by Cullinane and Khanna [36]. Conversely, as also asserted by Mulligan and Lombardo [37], a smaller average ship size may reflect a more diversified fleet with smaller vessels catering to specific routes or cargo types.

The analysis underscores the need for Türkiye to invest in young and large commercial vessels, offering two distinct approaches. Firstly, neglecting investment in younger, high-capacity vessels could escalate operating expenses, notably in insurance and maintenance, due to Türkiye's fleet being older than the global average. In fact, as asserted by Tran and Haasis [38] investing in new capacity will result in higher total revenue for operators, albeit at lower unit revenue. Moreover, older vessels may struggle to meet international maritime standards, limiting charterer options and market reputation. An aging fleet also hampers competitiveness during intense market competition. As implied by Alexandridis et al. [39] continuous investment in the maritime sector is vital to tackle these challenges effectively. Secondly, the regional nature of trade in the Mediterranean-Black Sea region, with smaller parcels, may hinder investment in large tonnage vessels. Introducing newer, larger ships requires a review of existing business models to align with market demands. Diversifying business models to engage in global trade beyond local regions could significantly enhance fleet performance. As outlined by Lorange and Fjeldstad [40], expanding operations geographically enables access to new opportunities and boosts efficiency. Indeed, Saya [41] emphasized that the development of Greek shipping was greatly influenced by the fact that Greek shipowners gained the ability to develop business by opening offices in maritime centers such as New York and London. This shows the significance of market access, which Türkiye also needs to prioritize.

The study's limitations include its reliance on data spanning from 2011 to 2023, the utilization of CRITIC and

TOPSIS methodologies among numerous multi-criteria decision-making methods, and the adoption of mean age, deadweight tons, and number of vessels as merchant fleet performance indicators. Future research could explore varying time frames and employ diverse methods and indicators for comparative performance assessment.

Author Contributions

All the authors equally contributed to this work. They all read and approved the final version of the paper.

Conflicts of Interest

All the authors declare no conflict of interest.

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